

Providing warmth for preterm babies by a heated, water filled mattress

I SARMAN AND R TUNELL

Department of Paediatrics, Huddinge Hospital, Karolinska Institute, Huddinge, Sweden

SUMMARY Seventeen healthy preterm babies had extra warmth provided in their cots by thermocontrolled, heated, water filled mattresses. As controls 17 babies of the same weight were nursed in air heated incubators. Both groups were studied for three weeks. No differences were found in minimal oxygen consumption (measured by indirect calorimetry), rectal and mean skin temperatures, or in daily weight gain. The babies were kept just as warm on the heated, water filled mattresses as in air heated incubators but the mattresses had the advantage of giving the mothers easy access to their babies.

Air heated incubators and thermocontrolled radiant heaters are most often used to warm preterm babies in modern neonatal care units. Both techniques are complex, expensive, and require a continuous electrical supply. These techniques are, therefore, not suitable for use in most developing countries. After recommendations from UNICEF, and a commission of the World Health Organisation, a heated, water filled mattress was developed as an alternative.¹

The present study was set up to compare the long term thermal effects of nursing healthy preterm infants in cots with the heated, water filled mattresses, with those of a control group of infants treated in single walled, air heated incubators.

Patients and methods

Each infant was cared for after birth during a stabilisation period in an air heated incubator. Thirty four premature or low birth weight, or both, infants were included in the investigation when they had reached a weight of 1400 to 1999 g. Infants who were free from infections, cardiopulmonary diseases, and gross malformations were studied as soon as they no longer needed supplementary oxygen. Informed consent from one or both parents was obtained.

The 34 babies were randomly allocated to either a study group who were nursed in cots on heated, water filled mattresses ($n=17$) or to a control group who were maintained in air heated incubators ($n=17$). The study period ran from the day of randomisation to the day when the baby moved to

an ordinary cot. This occurred for babies on the mattresses when the mattress temperature was 36°C, and for the incubator group when the air temperature in the incubator was 30°C, and the babies had normal, stable body temperatures.

The gestational age of all but two infants was determined from the early (16 to 17 weeks) ultrasonographic estimate of the fetal biparietal skull diameter. In two infants ultrasonographic examinations had not been performed and therefore post-natal maturity evaluation by Finnström's method was used.²

There were no significant differences between the groups in the mean age of the mothers, parity, or the gestational age. In both groups there were large proportions of caesarean sections—seven in the mattress group and 12 in the incubator group; in both groups the main indications had been intra-uterine growth retardation, or maternal toxæmia, or both (table 1). Four infants in the study group and six in the control group were classified as small for gestational age (below two standard deviations of birth weight, according to the Swedish national growth chart).³

There was no significant difference between the mean (SEM) stabilisation periods after birth in the two groups (11 (2) days (range 2–28) in the study group and 15 (4) days (range 3–55) in the control group). Five infants in each group were treated with supplementary oxygen for mild respiratory distress; all recovered without complications. Eleven babies in the study group and 13 in the control group needed phototherapy, but none received an exchange blood transfusion. All the mothers but one in each

group produced enough breast milk to feed their infants.

There was no significant difference between the mean (SEM) body weights of the infants in the study group and the control group ((SEM) 1595 (35) g (range 1400–1820) and 1569 (31) g (range 1430–1845)) at the start of the study period.

Table 1 *Characteristics of the study groups at birth*

	Heated, water filled mattress (n=17)	Incubator (n=17)	p Value
Mean (SEM) birth weight (g)	1567 (52)	1457 (83)	NS
Range	1130–1900	904–1980	
Mean (SEM) length at birth (cm)	41.9 (0.5)	40.1 (0.8)	≤0.005
Mean (SEM) head circumference (cm)	29.0 (0.4)	28.4 (0.6)	NS
Mean (SEM) gestational age (weeks)	32 (0.5)	32 (0.6)	NS
Range	29–35	28–35	
No of babies small for gestational age	4	6	

The heated, water filled mattress (Kanthal Medical Heating AB, Stockholm, Sweden) (fig 1) is a polyvinylchloride bag filled with 10 l water. The mattress is heated by a pad with heating foil covered by plastic and containing five built in thermistors. Two of the thermistors regulate the temperature, two are safety controls to avoid overheating, and one records the temperature of the mattress on a digital display. The heating pad is supplied with 24 V AC with a maximum effect of 50 W. The temperature can be regulated in seven steps between 35° and 38°C, and overheating as well as underheating alarms are built in. When the electricity supply is interrupted the alarm goes off. The mattress is placed in the crib. Each infant is dressed in a cotton shirt, a nappy and a cotton dress. If a baby weighs less than 1500 g he wears a cotton cap. Each infant is placed on the mattress and covered with a blanket.

The incubator used in the study was a single walled, manually controlled, air heated incubator AGA MK41 (AGA AB, Lidingö, Sweden). The infants in the incubators wore only nappies. Temperature adjustments of the mattresses and the incubators were made by the nursing staff after the

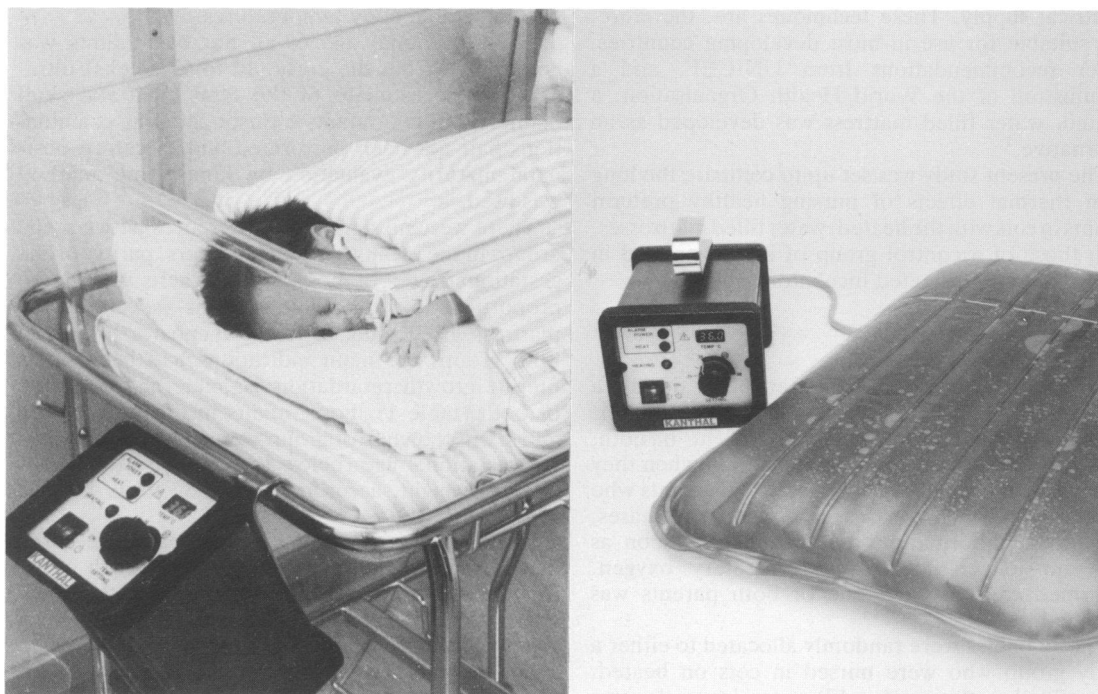


Fig 1 Heated, water filled mattress. The polyvinylchloride bag is filled with 10 l water. The temperature control unit is connected to the heating pad which is placed under the bag (right). Baby of 1500 g on the mattress, in a crib in the neonatal intensive care unit (left).

rectal temperatures of the babies had been recorded four times daily with a mercury thermometer. A rectal temperature between 36.5°C to 37.5°C was maintained.⁴ The nursery's ambient temperature was maintained at about 25°C (mean (SEM) 24.8 (0.02)°C).

All infants were fed breast milk by nasogastric tube, either with their mother's expressed milk or with a supplement of banked human milk. Feeding volumes were provided according to the recommendations of the European Society of Paediatric Gastroenterology and Nutrition—160 to 220 ml breast milk/kg body weight day after the first post-natal week.^{5,6}

The weight was recorded daily to the nearest 5 g and the rate of weight gain was calculated as g/kg body weight/day, and averaged for seven days. Skinfold thickness was measured once a week at five sites (biceps, triceps, subscapularis, flank, and quadriceps), using Harpenden calipers, and the mean skinfold thickness was calculated.⁷ Once a week, determinations of heat production and more exact temperature measurements were performed.

The infant's resting oxygen consumption as an indicator of heat production was determined by indirect calorimetry. A continuous open flow circuit method was used with a Plexiglas hood placed over the infant's head. For infants nursed on the mattress the air and wall temperatures of the hood were kept between 24°C and 25°C by circulating water through the inner wall of the hood. The flow of fresh air through the hood was measured with a Fleish pneumotacograph and regulated to achieve a carbon dioxide concentration of 0.5% in the diluted expired air. This resulted in an airflow of 1.0–2.5 l/minute. The pneumotacograph was calibrated against a Tissot spirometer. Air samples from the diluted expired air were drawn every fifth minute during the investigation period. The gas analyses were carried out with a paramagnetic oxygen analyser (Magnos 2T, Switzerland) and an infrared carbon dioxide analyser (Uras 3G, Switzerland). All the volumes were corrected for standard temperature and pressure, dry and computed on line.^{8,9} The system was calibrated before and after every investigation with ambient air and a known gas mixture (diluted air with 8% nitrogen and 2% carbon dioxide) using a mixing pump (H Vösthoff OHG, Type Eg725 Bochum, West Germany).

The infant's state of activity was recorded using Brück's method during the heat production measurements.¹⁰ Minimal oxygen consumption was calculated from the values obtained when the baby had been quietly sleeping during at least four periods of five minutes each. Simultaneously temperatures from the following sites were recorded every five minutes,

using thermocouples (Exacon 9000, Denmark): rectum (5 cm above the anus); skin (five sites—forehead, anterior abdomen, back, thigh, and foot); incubator air (centrally 10 cm above the infant's body); water in the heated mattress; and room air close to the baby.

The mean skin temperature was then calculated using weighting factors.¹¹ The accuracy of the thermocouples was checked several times against a 25 cm long mercury thermometer in a water bath at 20° and 40°C, and no deviation was found. The incubator air and the mattress water temperature were adjusted to the same temperature as that previously used.

The mean (SEM) and range were calculated to describe the group characteristics; for the quantitative differences between the groups the unpaired *t* test (one tail) was used, and for the frequency differences the χ^2 analysis, was used. A *p* value of ≤ 0.05 was accepted as significant.

Results

The duration of the study varied between infants because of differences in maturation and body weight at the start of the study period. Seventeen, 16, and nine infants in the study group, and 17, 16, and six infants in the control group were studied during one, two, and three weeks, respectively.

The mean weight gain (g/kg body weight/day) was slightly but not significantly higher, during all three of the study weeks in the group treated on the heated, water filled mattress, being 10.8 (2.0) and 8.0 (3.0) during week one, 15.0 (0.6) and 14.0 (0.6) during week two, and 15.5 (1.0) and 13.4 (1.5) during week three.

The mean breast milk feeding volume (ml/kg body weight/day) showed a slight but not significant difference during the first and third study weeks, being 167 (4.1) and 168 (6.5) during week one, 180 (4.1) and 182 (2.8) during week two, and 178 (3.4) and 184 (3.3) during week three. There were no significant differences in the mean skinfold thickness measurements during the study period, with an average gain of 0.4 mm/week for both groups.

Breast feeding was actively encouraged, but the number of mothers who were able to maintain it differed significantly between the groups. At discharge, 11 of 17 babies in the study group were fed only their own mother's breast milk, compared with five of 17 in the control group ($p \leq 0.05$). There was no difference in the duration of feeding by nasogastric tube between the two groups.

The results of oxygen consumption are given in table 2. They are given both as the minimal and the average values during the three hour measurement

Table 2 Mean (SEM) oxygen consumption (ml/kg/minute) in the two groups during the study period

Week	Heated, water filled mattress			Incubator			p Value
	No of babies	Minimal consumption	Average consumption	No of babies	Minimal consumption	Average consumption	
1	17	5.9 (0.2)	6.4 (0.2)	17	6.0 (0.1)	6.5 (0.2)	NS
2	16	6.9 (0.2)	7.6 (0.3)	16	6.8 (0.2)	7.6 (0.3)	NS
3	9	7.6 (0.1)	8.0 (0.1)	6	6.8 (0.2)	7.3 (0.1)	≤0.05

period. The minimal oxygen consumption periods occurred approximately two hours after the last meal. No significant difference was found in the minimal and average oxygen consumption during the first two weeks between the two groups. In the third study week, a significantly higher oxygen consumption was observed among babies in the study group ($p \leq 0.05$).

The results of the temperature measurements are shown in fig 2. There were no significant differences in the rectal or mean skin temperatures between the

groups, but the temperatures on the forehead and foot differed significantly. The mean forehead temperature of the infants in the study group was 1.5°C lower than that of the infants in the incubator group ($p \leq 0.001$). On the other hand, the peripheral skin temperature, measured as the foot temperature, was 1.5°C higher in the study group than in the incubator group over the same period ($p \leq 0.001$).

The water temperature of the mattress differed from the air temperature in the incubator. The water temperature was close to 36.5°C , with small variation among infants during the three study weeks. On the other hand, the air temperature of the incubator started at 33.5°C and decreased by 0.7°C – 0.8°C during the study period.

Discussion

The metabolic response of babies nursed in cots was studied in 1970 by Hey and O'Connell, who placed a warming element under an ordinary mattress. The oxygen consumption of 10 babies born at full term weighing 2000 to 3000 g decreased by 22% compared with the heat production recorded in unwarmed babies nursed in cots in an environment of 20°C .¹² The heat production of preterm babies in a cot with a heated, water filled mattress as heat source has not, to our knowledge, been reported. The mattress has several advantages over an ordinary heated mattress, including a high heat capacity, effective heat conduction, and a soft surface.

Our results indicate that the heat received from a heated, water filled mattress is equivalent to that from a conventional incubator. No difference was found in the minimal oxygen consumption, mean skin and body temperatures, and weekly weight gain. Our figures of minimal oxygen consumption in infants on a heated, water filled mattress confirm previous reports about infants in metabolic chambers or incubators.^{13 14}

Cot nursing entails exposing the infant's face to the temperature of the ambient room air which, in most nurseries and neonatal wards, varies between 20°C and 25°C . Mestyan *et al* reported that acute cooling of the faces of preterm babies causes a rapid

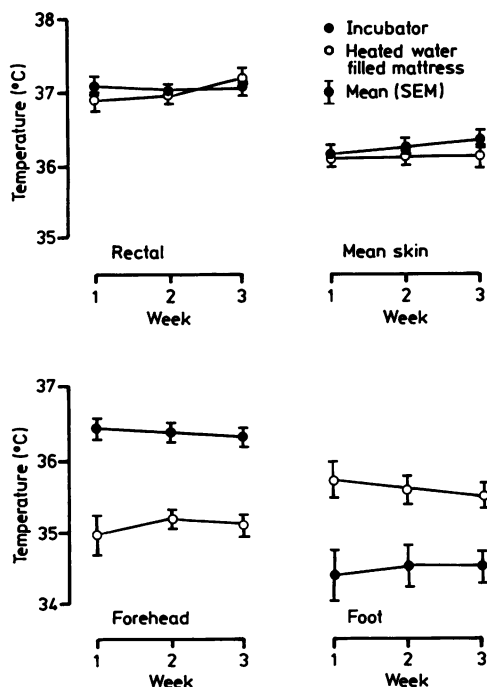


Fig 2 Changes in rectal, mean skin, forehead, and foot temperatures of babies treated on heated, water filled mattresses and in incubators during the three weeks of the study. During week 1 there were 17 babies in each group, during week 2 there were 16, and during week 3 there were nine and six, respectively; * $p < 0.001$.

increase in oxygen consumption.¹⁵ These results were not confirmed in our long term investigation. The baby nursed in a cot seems to adapt to the actual thermal conditions when treated continuously on the heated, water filled mattress, and does not increase its oxygen consumption although part of its face is cooled.

One specific advantage of this treatment is that it gives the mother easy access to her child and thus strengthens the early mother infant bonding. This may partly explain the significant increase in breast milk production on discharge from the hospital in the study group.

We conclude that the use of a heated, water filled mattress in a cot seems to be a simple, cheap, effective, and acceptable method of providing heat to healthy preterm babies who do not need intensive care in an incubator. This product can thus be an alternative to the incubator in both developing and developed countries.

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Correspondence and requests for reprints to Dr Sarman or Dr Tunell, Department of Paediatrics, B-59 Huddinge Hospital, S-141 86 Huddinge, Sweden.

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